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Acceptance of LNG as an alternative fuel: Determinants and policy implications

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ABSTRACT

The transport sector causes substantial greenhouse gas emissions and is responsible for the climate change and global warming. Introducing liquefied natural gas (LNG) as an alternative fuel for heavy-duty and long distance transport is an important strategy to increase the sustainability of the transport sector. Stakeholder's acceptance significantly influences the successful introduction of LNG. This paper examines the determinants of LNG acceptance. A causal model based on the technology acceptance framework is suggested and a structural equation model was estimated. Political implications are discussed to provide an insight which measures are effective to support the introduction of LNG as an alternative fuel. Results suggest that LNG as an alternative fuel can be fostered by stimulating demand, increasing the availability of LNG and improving the ecological effects of the fuel technology.

1. Introduction

Transport contributed a quarter of the total greenhouse gas emissions in the EU-28 in 2015. Road transport was responsible for almost 73% of the total greenhouse gas emissions from transport (EEA, 2017). These statistics clearly show that the transport sector in general and road transport in particular represent severe obstacles to the proper compliance with environmental targets. The introduction of alternative fuels and propulsion systems is therefore an important strategy that has also been anchored in the European Union's White Paper on Transport (European Commission, 2011).

Several alternative fuel technologies have emerged in the recent past. The problem is that most of them entail considerable restrictions when being used for heavy-duty vehicles or long distance transport. Electric vehicles are characterized by short ranges and long times for recharging, which currently limits their application basically to urban use and short distances (Engerer and Horn, 2010). Hydrogen has a high potential of reducing greenhouse gas emissions, but the production costs of hydrogen are still very high (Durbin and Malardier-Jugroot, 2013). The use of biofuels such as bioethanol and biodiesel is problematic due to their limited availability which occurs because land use is primarily dedicated for food production (Simio et al., 2013; Duarte et al., 2014).

The use of natural gas vehicles dates back to the 1930s. It is considered a mature technology that can be applied to a wide range of vehicles (Osorio-Tejada et al., 2015; Yeh, 2007). There are two different states in which natural gas can be used as vehicle fuel, either in a compressed state which is referred to as CNG (compressed natural gas), or in a liquid state which is referred to as LNG (liquefied natural gas). To convert natural gas to LNG, it has to be cooled down to a temperature of − 162 °C where it becomes liquid and reduces its volume roughly 600 times. LNG is a clear, colorless, odorless, non-toxic and non-corrosive cryogenic liquid. While CNG already finds widespread use for passenger cars, LNG is well suitable for heavy-duty vehicles due to the significantly high energy density that can be achieved through the volume reduction during the liquefaction process (Arteconi et al., 2010). As a matter of fact, LNG is the only viable and mature technology available that constitutes an alternative for diesel in the heavy-duty and long distance transport sector (Osorio-Tejada et al., 2015).

Environmental benefits of introducing LNG as alternative fuel include the clean combustion of LNG which causes nearly 99% less particle (PM) and sulfur oxide (SO_x) emissions, around 80% less nitrogen oxides (NO_x) and around 20% less carbon dioxide compared to diesel (Burel et al., 2013; Kumar et al., 2011). Emissions reduction can be even further enhanced by mixing liquefied bio-methane into the fuel (Kumar et al., 2011). Vehicles fueled with LNG also produce lower noise levels, which allows competitive advantages through inner-city and nighttime delivery services (Peters-von Rosenstiel et al., 2014).

Despite the high potential of reducing the negative impact of road transport, the fully fledged deployment of LNG was impeded in Central

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Table 1
Alternative fuel technology acceptance studies.

Reference	Research subject	Region	Determinants of acceptance
Wang et al. (2016)	Electric vehicles (hybrid)	China	Environmental concern, attitude toward adopting a hybrid electric vehicle (HEV), subjective norm, perceived behavioural control, personal moral norm, intention to adopt a HEV
Jayaraman et al. (2015)	Natural gas vehicles	Malaysia	Refueling station availability, payback period, petrol price, refueling time
Sang and Bekhet (2015)	Electric vehicles	Malaysia	Government intervention, environmental concern, performance attributes, social influence, financial benefits, demographic, infrastructure readiness
Huijts et al. (2014)	Hydrogen fuel stations	The Netherlands	Intention to act, attitude towards acting, perceived effects of the technology, subjective norm, perceived behavioural control, personal norm, outcome efficacy, environmental problem perception, energy security problem perception, problem perception, trust in the municipality, trust in the industry, distributive fairness, positive affect, negative affect
Hackbarth and Madlener (2013)	Alternative fuel vehicles	Germany	Purchase price, fuel cost, CO_2 emissions, driving range, fuel availability, refueling time, battery recharging time, policy incentives
van Rijnsoever et al. (2013)	Alternative fuel vehicles	Netherlands	Initial purchase price, fuel price, driving range, time to refuel, availability of fuel, local emissions
Tarigan et al. (2012)	Hydrogen vehicles	Norway	Demographic variables, knowledge, environmental attitude, willingness to pay more to purchase hydrogen vehicles
Kang and Park (2011)	Hydrogen vehicles	Korea	Psychological needs, perception towards hydrogen fuel cell vehicles, values, experience
Zhang et al. (2011)	Electric vehicles	China	Demographic variables, understanding of alternative fuel vehicles, experience, vehicle performance, government policy, environmental requirement, opinion of peers, vehicle price, tax reduction, fuel price, fuel availability, maintenance cost, vehicle safety
Thesen and Langhelle (2008)	Hydrogen vehicles and fuel stations	Norway/UK	Demographic variables, hydrogen support, environmental and hydrogen knowledge, attitude
Zachariah-Wolff and Hemmes (2006)	Hydrogen	The Netherlands	Demographic variables, knowledge, perception, attitude
O'Garra et al. (2005)	Hydrogen vehicles	United Kingdom	Demographic variables, environmental attitude, environmental knowledge, environmental behavior knowledge about hydrogen and fuel cells, attitude toward science and technology
Schulte et al. (2004)	Hydrogen vehicles	n.a.	Perception of product, values of person in question, wants of person in question, needs of person in question, past experience, social background

Europe for a long time. For many years, a chicken-and-egg problem dominated especially the landlocked countries: infrastructure such as refueling stations were not provided due to a lack of demand for LNG, and demand for LNG could not be signaled because potential customers had no infrastructure to use (Pfoser et al., 2016). In the meantime, though, political efforts have been made to fight the chicken-and-egg problem by stipulating the provision of LNG infrastructure. Through its Alternative Fuels Directive (2014/94/EU), the European Union set a policy framework to promote the construction of alternative fuels infrastructure to enable an increase in the uptake of alternative fuels vehicles and reduce Europe's dependence on oil and oil related products. Directive 2014/94/EU also encompasses LNG as it is a “cost-efficient technology allowing heavy-duty vehicles to meet the stringent pollutant emission limits of Euro VI standards” (European Union, 2014, p. 7). The importance of LNG for the European market is further underlined by the European Union's “Strategy for liquefied natural gas and gas storage” that has been released in 2016. This strategy aims at improving the access of all Member States to LNG as an alternative gas source and to exploit the full potential of LNG. Transport plays a key role within this strategy since it is expected that “LNG will increasingly be used as an alternative to marine fuels in shipping and to diesel in heavy duty vehicles such as lorries” (European Commission, 2016, p. 3).

The political efforts finally seem to be successful which is reflected by the most recent developments in Central Europe: the first LNG refueling station in Germany was opened in June 2016, the first LNG refueling station in Austria was opened in September 2017 (NGV Global, 2017). On the whole, a number of 101 LNG stations are currently operational in the EU/EFTA region, most of them in Spain (22 stations), the Netherlands (21 stations) and the UK (18 stations) (NGVA, 2017). An extension of the network is planned, thus the problem of supply (Arteconi and Polonara, 2013) seems to be tackled in a first step. This implies that the successful implementation of LNG is now subject to the development of demand, which is still restrained in Europe. The European Alternative Fuels Observatory estimates the total number of LNG vehicles in Europe at 1600 (EAFO, 2018).

Demand for LNG depends largely on its acceptance among potential users. Several authors stress the importance of understanding the acceptance of an alternative fuel for its introduction (e.g. Schulte et al., 2004; Zachariah-Wolff and Hemmes, 2006). However, only limited research has been conducted so far on the topic of alternative fuels acceptance, especially with regards to LNG. The objective of this paper is therefore to analyze stakeholder's acceptance of LNG as an alternative fuel. The determinants that influence acceptance of LNG (i.e. accessibility/availability of technology and refueling stations, attitude towards the use of alternative fuels, safety concerns towards LNG, expected usability as well as the expected usefulness of LNG) are examined in this study. These determinants provide important information for policy-makers as they reveal which incentives or regulations are most suitable to support the introduction of LNG (Huijts et al., 2014).

The remainder of this paper is structured as follows: Section 2 reviews existing literature on acceptance studies related to alternative fuels. A conceptual model of LNG acceptance is presented and the hypotheses of this study are derived. Later in Section 3, the methodology and sample of this study are described in deeper details. In Section 4, the main results are presented and extensively discussed. The paper concludes with an in-depth discussion of policy implications in Section 5.

2. Model and hypotheses

The concept of technology acceptance was first proposed by Davis in 1989 by introducing the technology acceptance model (Davis, 1989). The technology acceptance model (TAM) originally focused on assessing the acceptance of information technology, but by now it has already been employed on various other types of technologies, including alternative fuels and sustainable energy technologies (Chen et al., 2017). A lot of work has been published to refine TAM and expand the applications fields of this model. TAM is one of the most influential and most widely used extensions of the theory of reasoned action (Fishbein and Ajzen, 1977) and the theory of planned behavior (Ajzen, 1991).

As can be seen from Table 1, acceptance studies have been conducted for different types of alternative fuel technologies, including electric, hydrogen and natural gas vehicles. These studies have identified various determinants of individuals' acceptance of alternative fuel technologies (presented in Table 1). No study exists to date which is

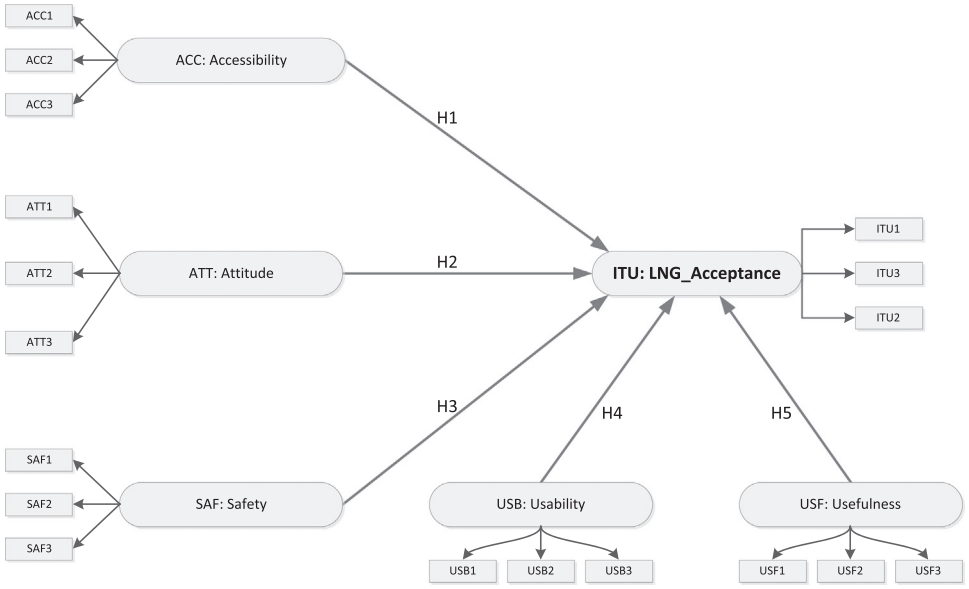

Fig. 1. The proposed conceptual model.

explicitly dedicated to the acceptance of LNG as an alternative fuel. Studies related to natural gas vehicles (e.g. Yeh, 2007 or Jayaraman et al., 2015) only refer to passenger cars, but not to heavy-duty vehicles. To address this gap, we derived a model that accounts for the specific characteristics of LNG based on the TAM and existing alternative fuel acceptance studies.

Our model includes five constructs to describe the individual acceptance of LNG as an alternative fuel (Fig. 1). These constructs are accessibility, attitude, safety, usability as well as usefulness. The model is considered to be appropriate in the present context since specific peculiarities of LNG application are incorporated, such as accessibility problems (chicken-and-egg situation) and safety concerns that are associated with the cryogenic fuel. Beyond that the model encompasses the basic constructs of Davis' TAM, which are attitude, perceived usefulness and perceived ease of use (called "usability" in our model).

It has been outlined in the introduction that accessibility is a major concern to the introduction and further development of LNG. Romm (2006) described the chicken-and-egg problem and stated that this would be the most challenging barrier in terms of accessibility and availability. The availability of the technology and sufficient infrastructure also influences an individual's acceptance of alternative fuels (Browne et al., 2012; Engerer and Horn, 2010; Ma et al., 2013). Sang and Bekhet (2015) state that infrastructure readiness plays a crucial role to increase market penetration. Arteconi and Polonara (2013) found that the use of LNG as a fuel is strongly related to refueling station distance. Beside the spread of refueling infrastructure, also the issue of efficiently supplying refueling stations might be a challenge (Arteconi and Polonara, 2013). Ma et al. (2013) argue that what mainly restrains the development of LNG vehicles today is not the cost of the vehicles or the price of LNG; instead, the main constraint is the lack of availability of LNG. Jayaraman et al. (2015) used "refueling station availability" as an independent variable in their model. These considerations lead to the first hypothesis:

Hypothesis 1. Accessibility/availability of technology and refueling stations determines an individual's acceptance of LNG.

Attitude is a construct that is included in many theoretical models, including TAM, theory of reasoned action or theory of planned behavior. Attitude describes an individual's cognitive beliefs and affects (Frambach and Schillewaert, 2002). Tarigan et al. (2012) report that a more positive attitude to the environment directly leads to greater support for hydrogen vehicles. Their findings offer consistent evidence that there is a causal relationship among knowledge, attitude and acceptance of alternative fuels (Tarigan et al., 2012). Sang and Bekhet (2015) describe environmental concerns as a determinant of electric vehicle usage. They define environmental concern as "the degree to which people are aware of problems regarding the environment and support the effort to solve them" (Sang and Bekhet, 2015, p. 77). This leads to the second hypothesis:

Hypothesis 2. Attitude towards alternative fuels determines an individual's acceptance of LNG.

Some studies about alternative fuels acceptance (e.g. Mourato et al., 2004; O'Garra et al., 2005) include the construct of safety since it is believed that safety is one of the key issues to secure acceptance of an alternative fuel. Browne et al. (2012) state that concerns about flammability and safety negatively affect public acceptance of alternative fuel vehicles. A quantitative study conducted by Zhang et al. (2011) even concludes that safety is the main influencing factor for public acceptance of alternative fuel vehicles. Interestingly, although safety is often named as a potential barrier of introducing alternative fuels, the studies that analyze this construct mostly find that it has only low influence on acceptance (Mourato et al., 2004; O'Garra et al., 2005). However, most of these studies address hydrogen and not natural gas. The use of natural gas vehicles is often associated with safety concerns because natural gas is either stored at high pressure or, in the case of LNG, at cryogenic temperatures (Bernatík et al., 2011). We therefore establish as the third hypothesis:

Hypothesis 3. Safety concerns determine an individual's acceptance of LNG.

The usability of a new technology, which is referred to as "perceived ease of use" by Davis (1989), can be defined as "the degree to which the prospective user expects the target system to be free of effort" (Davis et al., 1989, p. 985). Applied to alternative fuel technologies such as LNG, usability is given if similar or superior functional attributes to existing fuels are present, which makes it more likely that a new technology is accepted (Browne et al., 2012). Refueling time is an example for such a functional attribute, which can be seen as crucial feature in case it takes too much time compared with conventional fuels (Hackbarth and Madlener, 2013). In Sang and Bekhet (2015) this is referred to as "performance attributes", which includes performance considerations such as comfort, quietness or ease of driving. Another aspect of usability may be maintenance (Tzeng et al., 2005). The fourth

hypothesis of our model is therefore:

Hypothesis 4. Expected usability determines an individual's acceptance of LNG.

The probability that a technology is accepted also depends on the extent to which individuals believe that this technology will bring any improvements or lead to a better performance (Davis, 1989). This is also referred to as expected usefulness. In order to increase the acceptance of an alternative fuel, the perceived benefits of adopting that fuel should exceed the benefits of conventional fuels (Frambach and Schillewaert, 2002). Alternative fuel technologies might be regarded as useful if they bring economic or ecological benefits such as cost advantages, increased energy efficiency or reduction of negative external effects, e.g. noise (Tzeng et al., 2005). Especially financial benefits have always been an important motive for users to buy alternative fuel vehicles (see for example Heffner et al., 2007; Mourato et al., 2004; Sang and Bekhet, 2015). It has been even stated that price will always surpass environmental considerations (Bomb et al., 2007). This leads to the fifth and final hypothesis:

Hypothesis 5. Expected usefulness determines an individual's acceptance of LNG.

3. Methodology and sample

We tested the proposed model within potential users of LNG and stakeholders along the whole LNG value chain such as energy providers, equipment manufacturers or LNG supplying and distributing companies. The target group for this survey consists of representatives from companies, but the respondents in most of the previous alternative fuel acceptance studies (Table 1) were private persons. Our target group makes it difficult to achieve a large sample size, this is why we chose a rather broad area under study. The region covered by the survey includes the European Rhine-Main-Danube axis, where there are distinctive sectoral differences: The Rhine region, especially the Netherlands, is an exceptionally pioneering region with regard to LNG (Peters-von Rosenstiel et al., 2014) while the Danube area is currently in a development stage (Pfoser et al., 2016). For example, in the Netherlands there exist 23 filling stations to date, while many Danube countries (e.g. Romania, Bulgaria, Hungary) have not yet established any filling stations. The Rhine-Main-Danube corridor provides the main east-west link across Continental Europe and is one core corridor of the TEN-T network.

A standardized questionnaire has been designed with three items for each construct of the model (see Appendix A for a table containing detailed constructs and items). In order to establish the content validity of the items, the questionnaire was adopted and modified from an extensive literature survey. To categorize respondents into different stakeholder groups, we offered six groups to choose from: Energy, industry, logistics/transport, association, research/consulting and technology provider. These groups are based on the groups of stakeholders that have been defined by Yeh (2007) to be essential in the adoption of natural gas vehicles.

For scaling the responses, a seven-point Likert scale (ranging from 1 = completely disagree to 7 = completely agree) was used to specify the respondents' level of agreement or disagreement. A pretest with a group of academic experts from the transport sector was conducted to fine-tune the questionnaire. Afterwards the questionnaire was distributed online between June and August 2016 among the stakeholder database of a large European project on LNG called "LNG Masterplan". This database includes contacts from different companies and organizations that are interested or active in the LNG business. The online questionnaire made possible the collection of 157 responses. Table 2 shows details about the respondents' characteristics: they cover different parts of the LNG value chain, mostly research and consulting, logistics and transport as well as the energy sector. We collected questionnaires from a diverse number of countries all along the Rhine-Main-Danube corridor; most respondents came from Germany followed by the Netherlands and Austria.

4. Discussion and results

Fig. 2 gives an idea about respondent's background knowledge regarding alternative fuels for transport operations. As can be seen, the alternative fuels hydrogen and electricity are very familiar to the respondents (above 55% of respondents knew of these alternative fuels). However, the awareness of LNG was not that high (responses "I know much" and "I have heard about it" resulted lower than 45%). This is consistent with the findings of Kumar et al. (2011). Moreover, there is considerable unawareness regarding the use of biofuel as an alternative fuel (response "I do not know" represented more than 80%).

Analytical data in Table 3 indicate that the load of each item show a suitable value (greater than 0.6) for the majority of the examined constructs. As an exemption, we decided to discard one item (ATT 1 removed from the item list "attitude towards the use of alternative fuels") related to the so-called construct *Attitude* due to the very poor load provided to this factor (load lower 0.5).

Table 4 shows the results of the descriptive statistics related to the predictor variables and dependent variables. As can be seen, the absolute values of correlation coefficients are relatively low (all values below 0.3 and not significant considering alpha of 0.05), which give us a less concern regarding the multicollinearity problems. Furthermore, the results related to Cronbach´s alpha and composite reliability (CR) were above 0.71, overcoming the well-known recommended threshold value of 0.7 (Anderson and Gerbing, 1988). Also the computational results of the average variance extracted (AVE) are greater than 0.5 (see this threshold reported by Anderson and Gerbing (1988)), which indicates that the convergent validity is appropriated.

We compute the PLS algorithm using the dataset described in the previous section. Fig. 3 illustrates the structural model excluding one dropped item ATT 1. As shown in this graphical illustration, the five examined constructs explain a total of 52.6% of the variance (which implies a determination coefficient $R^2 = 0.526$). After a close look to Fig. 3 and Table 5, we could infer that all constructs, except the one called *Safety* (R^2 close to zero, very similar to the contributions of Mourato et al. (2004) and O'Garra et al. (2005)), provide a significant contribution aimed to understand the acceptance of LNG (response variable under study in this paper). Concretely, the *Accessibility* of LNG has a negative effect on the acceptance of this alternative fuel (coinciding with the statement of Romm (2006)), which can be inferred from the negative correlation coefficient ($-$ 0.117) of the ACC-Acceptance edge in Fig. 3. On the contrary, the Hypotheses 2, 4 and 5 were supported meaning that the *Attitude*, *Usability* and *Usefulness* have a significant positive influence on the acceptance of LNG. Examining the previous three independent variables, we can argue that the construct *Usefulness* has the highest positive influence (coefficient value bigger than 0.4) over the LNG acceptance.

The empirical data were collected from different managerial sectors, which give formidable opportunities to confront diverse point of view about the LNG overall acceptance. To this aim, Table 6 provides valuable information to understand that the Opinion-Group A (Logistic/Transport, Energy, Industry) and Opinion-Group B (Associations, Research/Consulting, Technology provider) influence very similar on the LNG acceptance. The minor difference resides on the significance level related to H1, which means that the LNG accessibility negative effect is disregarded according to both groups of respondents.

5. Conclusion and policy implications

Understanding the determinants of LNG acceptance is an important requirement to develop adequate and effective policy measures which support the introduction of LNG. The results of the structural equation

Table 2
Sample description.

Part of LNG value chain	Number of respondents	Countries of the Rhine-Main-Danube corridor										
		NL	BE	FR	DE	CZ	AT	SK	HU	BG	RO	other
Energy	15 (9.60%)	√			√		√			√		
Industry	41 (26.1%)	√		√	√	√	√	√		√	√	√
Logistics/Transport	21 (13.3%)	√	√		√		√		√		√	√
Associations	9 (5.70%)	√			√	√	√					√
Research/Consulting	51 (32.5%)	√	√		√	√	√	√			√	√
Technology provider	18 (11.5%)	√		√	√		√	√	√		√	
Not specified	2 (1.30%)				√							

The category "other" includes answers from neighbouring countries close to the Rhine-Main-Danube corridor such as Italy or Poland as well as not specified answers.

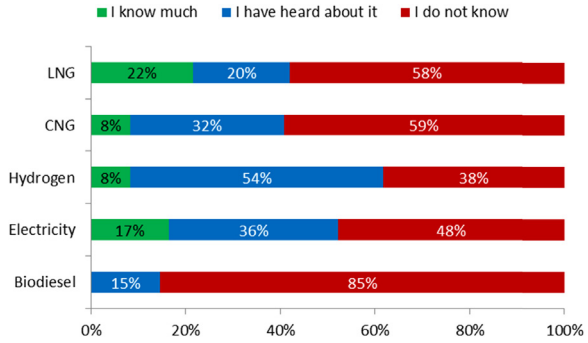

Fig. 2. Respondents 'awareness of alternative fuels for transportation.

Table 3
The loading of the items under study.

	Latent variables				
	Accessibility	**Attitude**	**Safety**	**Usability**	**Usefulness**
Retained items					
ACC 1	**0.913**				
ACC 2	**0.894**				
ACC 3	**0.923**				
ATT 2		**0.835**			
ATT 3		**0.873**			
SAF 1			**0.721**		
SAF 2			**0.905**		
SAF 3			**0.898**		
USB 1				**0.774**	
USB 2				**0.790**	
USB 3				**0.832**	
USF 1					**0.813**
USF 2					**0.774**
USF 3					**0.890**
Dropped item(s)					
ATT 1		**0.450**			

model suggest that accessibility, attitude, usability and usefulness directly influence acceptance of LNG. This information can be used by governments and policy makers to motivate potential users to adopt LNG vehicles. Fig. 4 presents a policy roadmap with measures that are suitable to facilitate the introduction of LNG. The measures were gathered from current literature and categorized based on the policy framework proposed in Peters-von Rosenstiel et al. (2014). The measures are classified into three groups with different objectives: stimulating LNG demand, increasing the availability of LNG and improving its ecological effects. The first two groups account for the two angles of the chicken-and-egg problem (demand and supply) while the third group accounts for the need to improve the environmental impact of LNG trucks (Peters-von Rosenstiel et al., 2014). Each measure depicted in the policy roadmap can be attributed to one or more determinants of the structural equation model, e.g. information campaigns can influence attitude, while security of investment and economic efficiency can influence the usefulness of LNG. Importantly, close cooperation between politics and industry will be necessary to establish the proposed measures and realize the market entry of LNG.

LNG as a fuel for heavy-duty vehicles is a relatively new technology and fleet operators only have limited knowledge about LNG compared to conventional fuels (Peters-von Rosenstiel et al., 2014). Knowledge about the benefits, features and safety issues of LNG could encourage potential users to introduce LNG and thus stimulates LNG demand (Jayaraman et al., 2015). Knowledge is positively linked to pro-environmental attitudes (Huijts et al., 2012; Tarigan et al., 2012), and attitude is a main determinant of LNG acceptance as suggested by the structural equation model. It is thus proposed that the adoption of LNG could be promoted through information campaigns and awareness programs which create knowledge (Browne et al., 2012). These campaigns are also suitable to diminish any safety concerns that fleet owners may have. During the last years, several LNG roadshows have been organized in different European countries in order to enable potential users testing the latest LNG truck technology. Within these events, visitors are allowed to drive LNG trucks, and they also learn how to refuel and maintain them. This reduces their fear and insecurities as they gain practical insights.

The higher cost of purchasing LNG fueled trucks is one of the main drawbacks for consumers because profitability is their most basic need towards introducing LNG (Ma et al., 2013; Pfoser et al., 2016). Governmental support in the form of monetary incentives for the acquisition of LNG vehicles is therefore a second essential measure to stimulate LNG demand beside information campaigns (Engerer and Horn, 2010; Osorio-Tejada et al., 2015; Wang et al., 2015). Monetary incentives either sponsor the fuel price (e.g. through tax credits and subsidies) or

Table 4
Descriptive analysis of the latent variables.

Constructs	Mean	S.D.	Cronbach´s α	Composite reliability (CR)	AVE	2	3	4	5
1. LNG_Acceptance	6.031	1.082	0.918	0.948	0.859				
2. Accessibility	5.055	1.493	0.896	0.935	0.828				
3. Attitude	6.258	0.825	0.730	0.843	0.729	0.156			
4. Safety	5.711	1.145	0.817	0.882	0.715	0.071	0.165		
5. Usability	5.252	1.373	0.719	0.841	0.638	0.103	0.125	0.125	
6. Usefulness	5.853	1.096	0.767	0.866	0.684	0.145	0.109	0.265	0.183

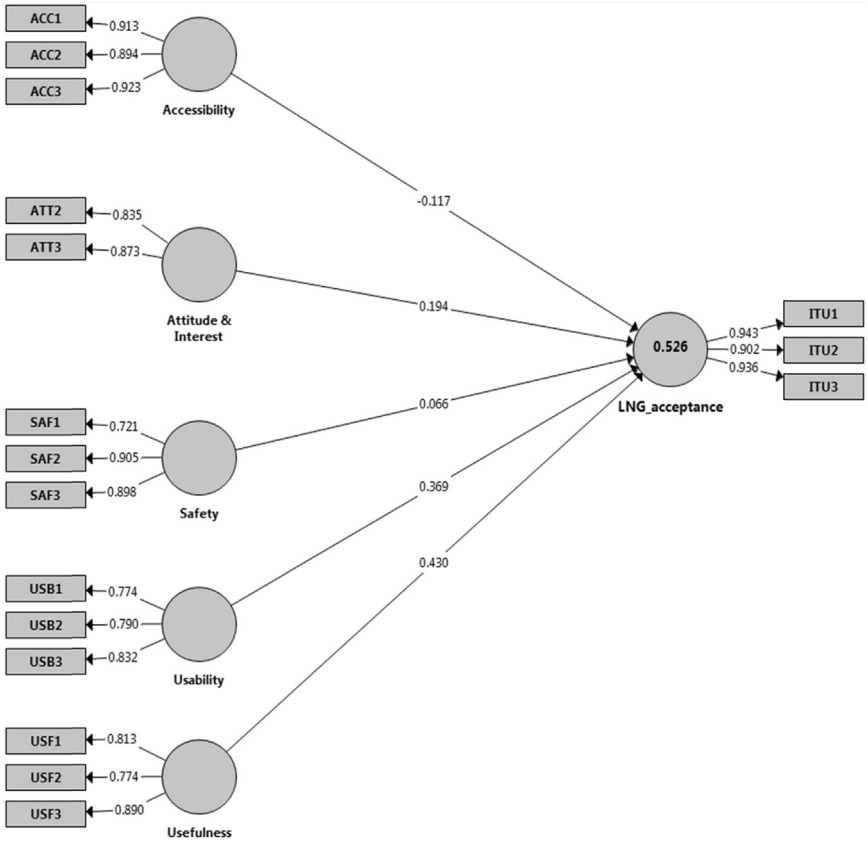

Fig. 3. The proposed structural model of LNG acceptance.

Table 5
Results of hypothesis testing based on the proposed structural model.

Hypothesis	Path coefficient	t-statistics (bootstrap)	*p*-value	Decision
H1	− 0.117	2.031	0.034	Supported
H2	0.194	2.944	0.003	Supported
H3	0.066	0.861	0.389	Rejected
H4	0.369	5.491	0.000	Supported
H5	0.430	6.077	0.000	Supported

vehicle prices (e.g. through rebates and loans) (Yeh, 2007). Several European countries have already established these types of monetary incentives. For example, there is an energy tax reduction in the Netherlands and some other countries (Peters-von Rosenstiel et al., 2014). In Sweden, the first 100 LNG trucks were subsidized with a bonus of 17,000€ per truck (Peters-von Rosenstiel et al., 2014). In Germany, the Ministry of Transport encouraged a logistics company to buy LNG trucks by funding a sum of 365,000€ for the first 20 trucks (Iveco, 2016). Also in Spain there exist governmental incentives of 20,000€ for each LNG truck purchased (Osorio-Tejada et al., 2017).

If sufficient demand is generated through the described stimulating measures, then the vehicle production costs can be reduced through mass production (Zhao and Melaina, 2006). This will result in lower technology costs, which is an important factor supporting the acceptance of LNG vehicles as technology costs directly influence the expected usefulness through financial benefits.

Besides stimulating LNG demand, efforts should be made at the same time to increase the availability of LNG. An efficient LNG infrastructure network must be developed to initiate both market penetration of vehicles as well as diffusion of refueling stations (Gorman, 1998). Practice examples for strategies to advance LNG infrastructure are US corporate income tax credits for fuel infrastructure construction or the European TEN-T infrastructure co-funding (Peters-von Rosenstiel et al., 2014). The LNG Blue Corridors Project can be named as a best practice example for facilitating LNG infrastructure diffusion. It was the first LNG project supported by the European Commission and has been running from 2013 to 2017. LNG Blue Corridors even surpassed a

Table 6
Group comparison considering the five proposed hypotheses.

Sector	Strata size	Hypothesis	Path coefficient	R^2	*p*-value	Decision
Logistic/Transport Energy Industry	77 (49.1)	H1	− 0.051	0.559	0.667	Rejected
		H2	0.251		0.023	Supported
		H3	0.008		0.941	Rejected
		H4	0.385		0.000	Supported
		H5	0.410		0.001	Supported
Associations Research/Consulting Technology provider	78 (49.7)	H1	− 0.154	0.547	0.218	Rejected
		H2	0.150		0.041	Supported
		H3	0.082		0.462	Rejected
		H4	0.343		0.003	Supported
		H5	0.492		0.000	Supported

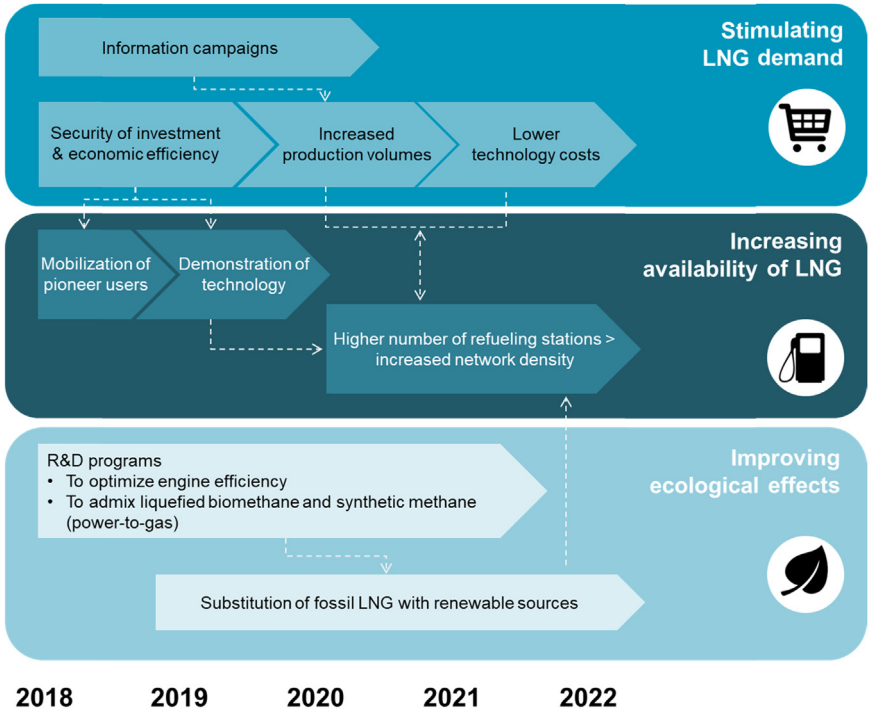

Fig. 4. Policy roadmap for the introduction of LNG.

number of infrastructure targets that have been set initially, for example it reached a number of 150 heavy-duty LNG-fueled trucks operating on the European roads which is 50 more than the initial target of 100 trucks. During project implementation, 43 fleet operators have opted to use LNG as fuel for their vehicles (LNG World News, 2017). This may constitute the demand push which is required to overcome the chicken-and-egg problem.

To prove the feasibility of LNG application, pioneer users should be mobilized and pilot trials should be conducted for demonstration purposes (Zhao and Melaina, 2006). From the pilot trials, “lessons learned” can be drawn which will help future users to operate this new technology. Demonstration of a technology creates “hands-on experience” which is often required by potential customers before investing in a new product (Schulte et al., 2004). Experience will generate a feeling of affectedness as benefits will be observed that are related to one's daily business (Schulte et al., 2004). This may convince users to switch to LNG which will in turn encourage the construction of refueling infrastructure. Government supported industry platforms such as the “National LNG Platform” in the Netherlands or the “LNG Taskforce” in Germany are appropriate to coordinate the mobilization and demonstration of activities within a country. For a successful operation of these platforms it is crucial that all types of relevant stakeholders are involved, including for example fuel suppliers, filling station operators, truck manufacturers and fleet operators.

The third group of policy measures illustrated in the roadmap deals with the improvement of the ecological effects of LNG. The significance of these measures is substantiated by a number of life cycle analyses that have been conducted by different authors (for a summary see Arteconi et al., 2010 or Kumar et al., 2011). These analyses conclude that the environmental impacts throughout the entire life cycle of LNG depend heavily on the specific production and transport processes. Depending on the particular scenario, the greenhouse gas emissions might not be much lower compared with diesel fuel, for example in the case that natural gas is liquefied two times from well to wheel (California Air Resources Board, 2008 in Arteconi et al., 2010). The positive ecological effects of LNG can be substantially increased if liquefied methane from renewable sources is admixed and if the energy efficiency of LNG engines is improved (Peters-von Rosenstiel et al., 2014). Renewable LNG can be produced from liquefied biomethane or liquefied synthetic methane (power-to-gas). To gain knowledge about engine efficiency and renewable methane sources, research and development (R&D) programs should be funded (Peters-von Rosenstiel et al., 2014). LNG, or natural gas in general, is often called a “bridging fuel” or a “transition fuel” (e.g. Howarth, 2014). The substitution of fossil LNG with renewable sources is an important step to advance LNG from a transition fuel to a sustainable long-term alternative fuel (Stephenson et al., 2012; Zhang et al., 2016).

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Appendix A

Constructs and items
Accessibility/availability of technology and refueling stations (ACC)
I think LNG technology is mature and available.
I think acquiring LNG technology involves similar effort as conventional technologies.
Switching from diesel to LNG seems complex to me.

Constructs and items

Attitude towards alternative fuels (ATT)
Alternative fuels will play an important role for the future energy mix.
Fleet operators should gain current knowledge of alternative fuels.
We already use or do some work on alternative fuel technologies.
Safety concerns (SAF)
I think undesirable effects such as damages are improbable when using LNG technology.
Dangerous situations in handling LNG can be avoided if the staff is well trained.
Accidents resulting from the cold temperatures of LNG are rarely seen.
Expected usability (USB)
The introduction of LNG vehicles would keep a fleet operator's daily operations as they were before.
Employees would be capable to handle LNG technology.
Learning how to control LNG technology would be easy to understand.
Expected usefulness (USF)
Compared with diesel, LNG technology could help a company achieving its environmental and social sustainability goals.
LNG technology would support the strategic targets of a fleet operating company.
The introduction of LNG could enhance the ecological footprint of a company.
Intentions to use (ITU)
LNG is a feasible fueling option for fleet operators.
LNG is suitable for a fleet operator's future performance.
I support LNG as a favorable alternative transportation fuel for operating fleets.

Likert scale: 1 = completely disagree, 2 = disagree, 3 = partly disagree, 4 = neither agree nor disagree, 5 = partly agree, 6 = agree, 7 = completely agree.

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